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Description

This invention relates to a measuring instrument, employing a hall element, for determining the value of a wide variety of parameters in a system. It is particularly useful in measuring electrical current of any waveshape, including d—c, a—c or d—c with superimposed a—c.

Current sensors have been developed wherein a hall element (or hall effect generator) responds to the magnetic flux, produced by the current to be measured, to provide a voltage which is proportional to and represents the current. A major advantage of a hall effect sensor is that it may be clamped on the conductor carrying the measured current and will be electrically isolated from that conductor. In one particular type of sensor as disclosed in CH—A—580 282, the hall element is subjected to two opposing magnetic fluxes, one produced by the current in the conductor to be measured and the other by a cancellation circuit. The current in the cancellation circuit is adjusted so that the two fluxes cancel each other, the net flux in the hall element thereby becoming zero. The amplitude of the cancelling current is therefore a function of, and provides a measure of, the magnitude of the sensed current.

Unfortunately, the accuracy of these prior hall element sensors suffers with temperature changes and aging. As a hall element ages or its temperature varies, its performance characteristics change and may even become non-linear. Hence, erroneous measurements may be obtained under those conditions. In contrast, the sensing system of the present invention, although also employing a hall element, achieves highly accurate measurements and is immune to the deleterious effects of temperature, aging and non-linearity. Moreover, these improved results are accomplished by means of a relatively simple and inexpensive circuit arrangement utilizing a low-cost hall element.

The sensing system of the invention comprises a hall element and means for establishing, in the hall element, a first or energizing magnetic flux having a magnitude which is a function of a parameter, such as the current passing through a conductor, to be measured. The resulting hall voltage, produced by the hall element, will have a polarity and an amplitude determined by the first magnetic flux. A polarity detector, coupled to the hall element, develops an output voltage of a polarity determined by that of the hall voltage. The integral of that output voltage controls a cancelling means to establish, in the hall element, a second or cancelling magnetic flux of equal magnitude but of opposite direction relative to the first or energizing magnetic flux, the net flux in the hall element, and the resulting hall voltage, thereby tending to become zero. Means, included in the cancelling means, produce a control voltage which is proportional to and represents the measured parameter. By effectively operating the cancelling means in response to only the polarity of the hall voltage, the sensing system will be immune to any changes in the amplitude of the hall voltage caused by aging, temperature variations or non-linear effects in the hall element.

The features of the invention which are believed to be novel are set forth particularly in the appended claims. The invention may best be understood, however, by reference to the following description in conjunction with the accompanying drawing in which:

FIGURE 1 schematically illustrates a sensing system, constructed in accordance with one embodiment of the invention, for measuring a parameter in a system, specifically the current flowing through a conductor;

FIGURE 2 shows the relationship between the magnetic flux and the resultant hall voltage in the hall element included in FIGURE 1; and

FIGURE 3 discloses another embodiment of the invention, the sensing system measuring a parameter or variable, such as pressure, which effects movement of an actuator.

Referring to FIGURE 1, conductor 10 carries the current to be measured, and this current may be d—c flowing in either direction, a—c or a—c with a d—c offset. It may have any amplitude from a few amperes to hundreds of amperes and may have any waveshape and frequency from d—c to greater than 10 kilohertz. Hall element 12 is located in the air gap of the magnetic core formed by the two portions 13a and 13b, which are shown by an exploded view in FIGURE 1. With this arrangement, the magnetic core 13a, 13b may be clamped on or over conductor 10 to measure its current without requiring disconnecting of the conductor from the circuit in which it is coupled. Moreover, this permits the current sensor to be electrically isolated from conductor 10. Of course, the diameter of conductor 10 and the physical dimensions of the magnetic core will depend on the magnitude of the current carried by the conductor.

With the core 13a, 13b surrounding or encompassing conductor 10, most of the magnetic flux, created by the current flowing through the conductor, will be concentrated within the core and directed to the hall element 12. As is well understood, a hall element, or hall effect generator, develops a voltage (called a hall voltage) having a polarity and an amplitude which are functions of the flux passing through the hall element, the polarity of the hall voltage being determined by the flux direction (hence the direction of current flow in conductor 10) while the amplitude of the hall voltage is directly proportional to the magnitude or density of the flux, and thus to the amplitude of the current in the conductor. This relationship is shown in FIGURE 2. It should be realized that the magnetic core 13a, 13b is not essential. All that is necessary is for the current in conductor 10 to establish, in the hall element 12, a magnetic flux having a strength which is a function of that current. Utilizing a core will contain the flux so that for a given current more flux will pass through the hall element.

Unfortunately, the performance of a hall

element is greatly affected by temperature and age. As a hall element ages or its temperature changes, the ratio of voltage to magnetic flux changes, and this changes the slope of the performance line or curve in FIGURE 2. Furthermore, the line may even become non-linear. Such variations in performance of hall elements have resulted in inaccurate current measurements in the past. In accordance with a salient feature of the invention, only the polarity of the hall voltage is used and not the magnitude. This makes the current sensing system of FIGURE 1 relatively free from temperature, age and non-linear effects. Lower cost and even non-linear hall elements may thus be employed since the hall voltage magnitude has no meaning in the invention.

This important feature is implemented by applying the hall voltage to polarity or sign detector 15 over conductors 17 and 18. Unless the hall voltage is zero, the polarity detector produces an output voltage of fixed or constant magnitude but of a polarity as determined by the sign of the hall voltage. In other words, if the hall voltage is positive and of any amplitude above zero, the output of the polarity detector 15 will also be positive and of fixed amplitude. On the other hand, any negative voltage whatsoever from the hall element results in a negative output voltage of a fixed value from polarity detector 15. Thus, if current flows through conductor 10 in one direction the output of the polarity detector will be positive, whereas if current flows through the conductor in the other direction the detector output will be negative. Since the magnitude of the voltage out of the polarity detector 15 is in no way a function of the magnitude of the hall voltage, the polarity detector successfully eliminates all aging, temperature and non-linear effects of the hall element 12.

The output of polarity detector 15 is applied to an integrator 19 which integrates in either a positive direction (ramping up) or a negative direction (ramping down) depending on the sign of the detector output voltage. The signal out of the integrator feeds the current amplifier 21 which boosts the signal from the integrator so there is enough current to drive the winding or coil 22 which is wrapped around the magnetic core 13a, 13b. The function of winding 22 is to produce a cancelling flux of opposite polarity or direction to the energizing flux produced by the current in conductor 10. The cancelling flux produced by coil 22 is proportional to the driving current received from the current amplifier 21 which, in turn, is proportional to the output voltage of integrator 19.

Assume, for example, that d—c current flows through conductor 10 in a direction to create a clockwise energizing flux in the core, and assume that such a flux develops a positive voltage out of detector 15. Integrator 19 continues to integrate in a positive direction, in response to the detector output voltage, to produce an increasing counter-clockwise cancelling flux in core 13a, 13b until the net flux in the core becomes zero. At this point, the first or energizing flux produced by the current in conductor 10 and the second, opposite direction cancelling flux produced by the current in winding 22 will be of equal magnitude. The resulting hall voltage thus goes to zero and the output of detector 15 becomes a high frequency oscillation (due to the fact that the sign of zero is indeterminate) whose average value is zero. The average zero value from detector 15 causes the integrator 19 to hold its present value which causes a constant driving current to flow in cancelling coil 22 tos flow in cancelling coil 22 to produce just enough flux to cancel the flux produced by the current in conductor 10.

The amount of current needed in coil 22 to cancel the energizing flux produced by the current in conductor 10 is dependent on the number of turns on the coil and also the number of turns on conductor 10. Assuming N_1 turns for conductor 10, N_2 turns on coil 22 and a current I_1 in conductor 10, the driving current I_2 required in coil 22 is equal to I_1 multiplied by the ratio N_1/N_2. Hence, if the current I_1 to be measured is relatively small an input coil would be wrapped around the core, thereby increasing the sensitivity. Since the driving current I_2 also flows through the series-connected limiting resistor 23, the voltage produced across the resistor will be proportional to and will represent the current to be measured in conductor 10. This voltage constitutes a control voltage that can be sensed by meter 24 to provide an indication or display of the magnitude of the current in conductor 10 or can be used to control logic circuitry or some other system.

Any change in current in conductor 10 causes the hall voltage to have a value other than zero and this in turn causes the integrator to move in a direction which changes the current in winding 22 as necessary to effect zero net flux in core 13a, 13b. For example, if the current in conductor 10 increases, the hall element 12 produces a positive voltage causing the polarity detecter 15 to issue a positive voltage. Integrator 19 thereupon resumes integrating in a positive direction (ramping up) and the driving current through winding 22 increases to increase the cancelling flux. This continues until the two fluxes are equal, at which time the hall voltage drops to zero and the loop will once again be stabilized. The increased current in conductor 10 will now be indicated by a higher voltage drop across resistor 23. If the current were to decrease in conductor 10, the flux produced by coil 22 would exceed that created by conductor 10 and the hall voltage would become negative. The output voltage of detector 15 therefore becomes negative and integrator 19 begins to integrate in a negative direction (ramping down), causing the current in coil 22 to decrease to the extent necessary to balance out the two fluxes. The hall voltage thus returns to zero and the lower current in resistor 23 represents the lower current in conductor 10.

It will now be apparent that the current in conductor 10 may change in accordance with any waveform and the sensing system will follow or

track the changes, producing a control signal across resistor 23 which is either a reduced-amplitude replica or an amplified replica of the current in conductor 10, depending on the N_1/N_2 turns ratio. In other words, the waveforms of the currents through conductor 10 and through resistor 23 will be similar. As mentioned, the current in conductor 10 may be a—c superimposed on d—c. For example, in an inverter-motor system the sensing system may be used to measure d—c bus current which may also have a high frequency ripple. In actual practice it has been found that the sensing system disclosed herein is capable of measuring currents from d—c to a—c having frequencies greater than 10 kilohertz.

It will be appreciated that the invention is susceptible of many different variations. A variety of different parameters may be measured by modifying the FIGURE 1 embodiment. For example, when a sensed parameter, such as pressure, distance, etc., physically moves some device, such as a piston, diaphragm, etc., the movement of the device may be employed to adjust the magnitude of the energizing flux passing through the hall element. Such an embodiment is illustrated in FIGURE 3. There, sensor 28 represents some sensing mechanism that moves in response to some parameter, such as to a diaphragm whose position is determined by pressure. Dashed construction line 29 schematically illustrates an actuator that establishes the position of magnet 31 in response to the position of the diaphragm. The magnitude of the energizing flux in the hall element 12 will now be a function of the distance between magnet 31 and the hall element, indicated by X in FIGURE 3. As the magnet is moved closer to hall element 12 the flux increases and as the magnet is moved away the flux decreases. The rest of the circuit in FIGURE 3 operates in a similar fashion as in FIGURE 1. The cancelling coil 32 has a magnetic core 33 which helps to contain and amplify the flux produced by the coil, and this flux is then used to cancel the energizing flux from magnet 31. Detector 15, integrator 19 and current amplifier 21 in FIGURE 3 respond to the hall voltage, in the manner discussed previously, to produce the necessary current in winding 32 to nullify the flux developed by magnet 31, thereby maintaining a zero hall voltage. Meter 24 will hence provide a measurement of the parameter sensed by sensor 28.

Claims

1. A sensing system for measuring a parameter, comprising:

a hall element (12);

means (10, 13a, 13b, 28—31) for establishing, in said hall element, a first magnetic flux having a magnitude which is a function of the parameter to be measured,

said hall element (12) thereby producing a hall voltage having a polarity and an amplitude determined by the first magnetic flux;

cancelling means (21—23, 32, 33) for establishing, in said hall element, a second magnetic flux of equal magnitude but of opposite direction relative to the first magnetic flux, the net flux in said hall element, and the resulting hall voltage, thereby tending to become zero;

and means (23), included in said cancelling means, for producing a control voltage which is proportional to and represents the measured parameter,

characterized by

a polarity detector (15), coupled to said hall element, for developing an output voltage of a polarity determined by that of the hall voltage;

an integrator (19) for integrating the output voltage of said polarity detector;

said cancelling means (21—23, 32, 33) establishing the second magnetic flux in response to the integrator output voltage.

2. A sensing system according to Claim 1 and including a meter (24), operated by said control voltage for indicating the value of the measured parameter.

3. A sensing system according to Claim 1 wherein the output voltage of said polarity detector (15) has a fixed magnitude and the same polarity as said hall voltage when the magnitude of said voltage is other than zero.

4. A sensing system according to Claim 1 wherein said cancelling means includes a cancelling (22, 23) winding to which driving current is supplied to produce the second magnetic flux, said control voltage being developed in response to the driving current.

5. A sensing system according to Claim 4 wherein the driving current flows through a series-connected current limiting resistor (23), the voltage across the resistor constituting said control voltage.

6. A sensing system according to Claim 1 wherein said cancelling means includes a current amplifier (21) whose input couples to the output of said integrator and whose output supplies current to and drives a cancelling (22, 32) winding to develop the necessary second magnetic flux.

7. A sensing system according to Claim 1 wherein both the direction and magnitude of the first magnetic flux are determined by the parameter to be measured.

8. A sensing system according to Claim 1 wherein the current flowing through a conductor (10) constitutes the parameter to be measured and produces the first magnetic flux, the magnitude of the flux being determined by the current amplitude while the direction of the flux is determined by the direction in which the current flows through said conductor.

9. A sensing system according to Claim 8 wherein a magnetic core (13a, 13b), within which said hall element is inserted, encompasses said conductor to contain and concentrate the first magnetic flux and to direct it to said hall element.

10. A sensing system according to Claim 9 wherein said cancelling means includes a cancelling winding (22) wrapped around said magnetic

core to concentrate the second magnetic flux and direct it to said element to oppose the first magnetic flux.

11. A sensing system according to Claim 1 wherein a movable actuator (29), in response to the sensed parameter, effectively adjusts the magnitude of the first magnetic flux passing through said hall element.

12. A sensing system according to Claim 11 wherein said actuator varies the position of a magnet (31) in order to adjust the magnitude of the first magnetic flux in said hall element.

13. A sensing system according to Claim 12 wherein said cancelling means includes a winding (32) wound on a magnetic core (33) for producing the required second magnetic flux.

Patentansprüche

1. Abtastvorrichtung zum Messen eines Parameters, mit:

einem Hallelement (12);

einer Einrichtung (10, 13a, 13b, 28—31), um im Hallelement einen ersten Magnetfluß eines Wertes herzustellen, der eine Funktion des zu messenden Parameters ist,

wobei das Hallelement (12) dadurch eine Hallspannung einer Polarität und einer Amplitude erzeugt, die durch den ersten Magnetfluß bestimmt sind;

einer Löscheinrichtung (21—23, 32, 33), um im Hallelement einen zweiten Magnetfluß gleichen Wertes, jedoch entgegengesetzter Richtung bezogen auf den ersten Magnetfluß herzustellen, wobei der Nutzfluß im Hallelement und die resultierende Hallspannung dadurch zu Null tendiert;

und einer Einrichtung (23), die in der Löscheinrichtung enthalten ist und eine Steuerspannung erzeugt, die zum gemessenen Parameter proportional ist und diesen darstellt,

gekennzeichnet durch

einen Polaritätsdetektor (15), der mit dem Hallelement verbunden ist und eine Ausgangsspannung einer Polarität erzeugt, die durch die der Hallspannung bestimmt wird;

einen Integrator (19) zum Integrieren der Ausgangsspannung des Polaritätsdetektors;

wobei die Löscheinrichtung (21—23, 32, 33) den zweiten Magnetfluß in Abhängigkeit von der Integratorausgangsspannung herstellt.

2. Vorrichtung nach Anspruch 1, gekennzeichnet durch eine Meßgerät (24), das von der Steuerspannung betätigt wird und der Wert des gemessenen Parameters anzeigt.

3. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Ausgangsspannung des Polaritätsdetektors (15) einen festen Wert und dieselbe Polarität wie die Hallspannung aufweist, wenn der Wert der Hallspannung von Null abweicht.

4. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Löscheinrichtung eine Löschwinklung (22, 32) enthält, der Antriebsstrom zugeführt wird, um den zweiten Magnetfluß zu erzeugen, wobei die Steuerspannung in Abhängigkeit vom Antriebsstrom erzeugt wird.

5. Vorrichtung nach Anspruch 4, dadurch gekennzeichnet, daß der Antriebsstrom durch einen in Reihe geschalteten Strombegrenzungswiderstand (23) fließt, wobei die Spannung über dem Widerstand die Steuerspannung darstellt.

6. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Löscheinrichtung einen Stromverstärker (21) enthält, dessen Eingang mit dem Ausgang des Integrators verbunden ist und dessen Ausgang einer Löschwicklung (22, 32) Strom zuführt und sie antreibt, um den erforderlichen zweiten Magnetfluß zu erzeugen.

7. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Richtung wie auch der Wert des ersten Magnetflusses durch den zu messenden Parameter bestimmt werden.

8. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß der durch einen Leiter (10) fließende Strom den zu messenden Parameter darstellt und den ersten Magnetfluß erzeugt, wobei der Wert des Flusses durch die Stromamplitude, die Richtung des Flusses hingegen durch die Richtung bestimmt wird, in der der Strom durch den Leiter fließt.

9. Vorrichtung nach Anspruch 8, dadurch gekennzeichnet, daß ein Magnetkern (13a, 13b), in dem das Hallelement eingesetzt ist, den Leiter umgibt, um den ersten Magnetfluß aufzunehmen und zu konzentrieren und ihn zum Hallelement zu lenken.

10. Vorrichtung nach Anspruch 9, dadurch gekennzeichnet, daß die Löscheinrichtung eine Löschwicklung (22) enthält, die um den Magnetkern gewickelt ist, um den zweiten Magnetfluß zu konzentrieren und ihn zum Hallelement zu lenken, um dem ersten Magnetfluß entgegenzuwirken.

11. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß eine bewegliche Stelleinrichtung (29) in Abhängigkeit vom abgetasteten Parameter den Wert des ersten Magnetflusses wirksam einstellt, der durch das Hallelement fließt.

12. Vorrichtung nach Anspruch 11, dadurch gekennzeichnet, daß die Stelleinrichtung die Stellung eines Magnets (31) verändert, um den Wert des ersten Magnetflusses im Hallelement einzustellen.

13. Vorrichtung nach Anspruch 12, dadurch gekennzeichnet, daß die Löscheinrichtung eine Wicklung (32) enthält, die auf einen Magnetkern (33) gewickelt ist, um den erforderlichen zweiten Magnetfluß zu erzeugen.

Revendications

1. Système de détection pour la mesure d'un paramètre, comprenant:

— un élément à effet Hall (12);

— des moyens (10, 13a, 13b, 28—31) pour établir dans l'élément à effet Hall, un premier flux magnétique ayant une intensité qui est fonction du paramètre à mesurer;

— l'élément à effet Hall (12) produisant ainsi une tension par effet Hall ayant une polarité et une amplitude déterminées par le premier flux magnétique:

— un moyen d'annulation (21—23, 32, 33) pour établir dans l'élément à effet Hall, un second flux magnétique d'intensité égale mais de sens opposé au premier flux magnétique, le flux net dans l'élément à effet Hall et la tension par effet Hall résultante, tendant ainsi à s'annuler;

— et un moyen (23), inclus dans le moyen d'annulation, pour produire une tension de commande qui est proportionnelle au paramètre mesuré et représente ce dernier;

caractérisé par:

— un détecteur de polarité (15), couplé à l'élément à effet Hall, pour développer une tension de sortie d'une polarité déterminée par celle de la tension par effet Hall;

— un intégrateur (19) pour intégrer la tension de sortie du détecteur de polarité;

— le moyen d'annulation (21—23, 32, 33) établissant le second flux magnétique en réponse à la tension de sortie de l'intégrateur.

2. Système de détection selon la revendication 1 et comprenant un appareil de mesure (24) actionné par la tension de commande pour indiquer la valeur du paramètre mesuré.

3. Système de détection selon la revendication 1, dans lequel la tension de sortie du détecteur de polarité (15) a une amplitude fixe et la même polarité que la tension par effet Hall lorsque l'amplitude de la tension par effet Hall est autre que zéro.

4. Système de détection selon la revendication 1, dans lequel le moyen d'annulation comporte un enroulement d'annulation (22, 23) auquel est fourni un courant d'attaque pour produire le second flux magnétique, la tension de commande étant développé en réponse au courant d'attaque.

5. Système de détection selon la revendication 4, dans lequel le courant d'attaque traverse une résistance (23) de limitation de courant montée en série, la tension aux bornes de la résistance constituant la tension de commande.

6. Système de détection selon la revendication 1, dans lequel le moyen d'annulation comprend un amplificateur de courant (21) dont l'entrée est couplée à la sortie de l'intégrateur et dont la sortie fournit du courant à un enroulement d'annulation (22, 32) et l'attaque afin de développer le second flux magnétique nécessaire.

7. Système de détection selon la revendication 1, dans lequel le sens et l'intensité du premier flux magnétique sont déterminés par le paramètre à mesurer.

8. Système de détection selon la revendication 1, dans lequel le courant traversant un conducteur (10) constitue le paramètre à mesurer et produit le premier flux magnétique, l'intensité du flux étant déterminée par l'amplitude du courant alors que le sens du flux est déterminé par le sens dans lequel le courant traverse le conducteur.

9. Système de détection selon la revendication 8, dans lequel un noyau magnétique (13a, 13b) dans lequel l'élément à effet Hall est inséré, enferme le conducteur pour contenir et concentrer le premier flux magnétique et pour le diriger vers l'élément à effet Hall.

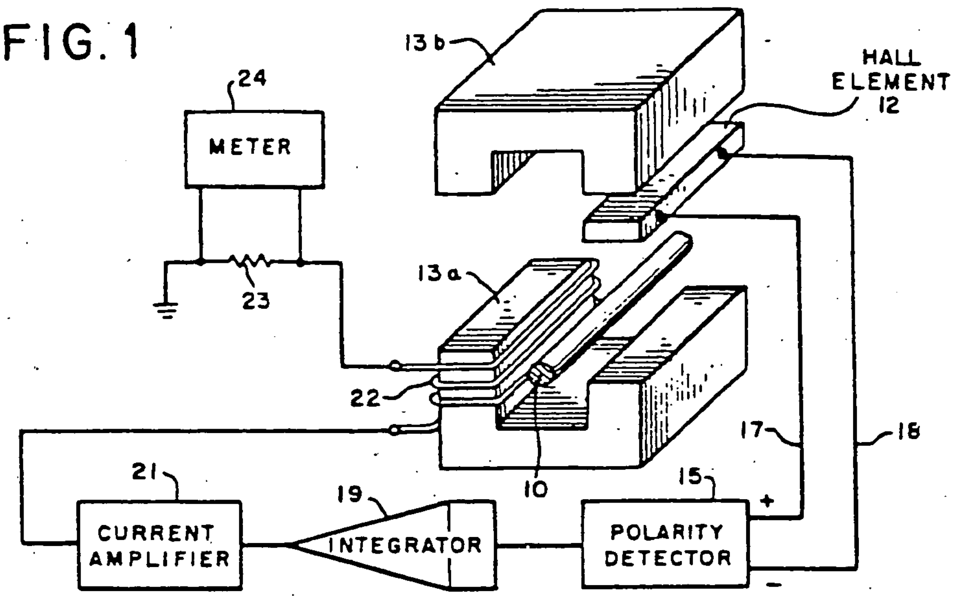
10. Système de détection selon la revendication 9, dans lequel le moyen d'annulation comprend un enroulement d'annulation (22) enroulé autour du noyau magnétique pour concentrer le second flux magnétique et le diriger vers l'élément à effet Hall afin qu'il s'oppose au premier flux magnétique.

11. Système de détection selon la revendication 1, dans lequel un actionneur mobile (29) en réponse à la détection du paramètre, ajuste effectivement l'amplitude du premier flux magnétique traversant l'élément à effet Hall.

12. Système de détection selon la revendication 11, dans lequel l'actionneur modifie la position d'un aimant (31) de manière à ajuster l'intensité du premier flux magnétique dans l'élément à effet Hall.

13. Système de détection selon la revendication 12, dans lequel le moyen d'annulation comprend un enroulement (32) bobiné sur un noyau magnétique (33) pour produire le second flux magnétique nécessaire.

FIG. 1



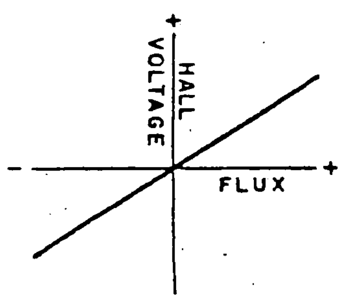


FIG. 2

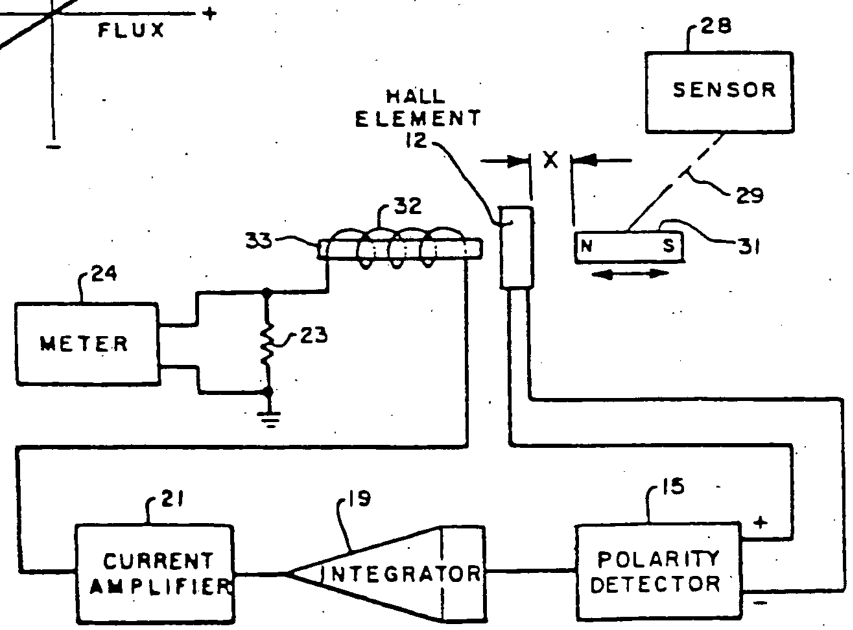


FIG. 3

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